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THE CONTROL OF FROG-EYE ON APPLE

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THE CONTROL OF FROG-EYE ON APPLE

R. C. Walton

SUMMARY

1. The facts presented in this bulletin are the results of two seasons' work on the control of frog-eye.

2. Frog-eye is a leaf disease of the apple caused by the fungus *Physalospora Cydoniae* (*Sphaeropsis malorum*).

3. Frog-eye is so serious a disease in parts of Pennsylvania as to cause almost complete defoliation by August with the result that the fruit is undersized and the trees are weakened.

4. Severe attacks of frog-eye result in undersized fruit, loss in vitality to the trees, weakened fruit buds, and eventually death to the trees if the attacks continue unchecked.

5. But little difference has been noted in the susceptibility of varieties, practically all those under observation being subject to infection. The two varieties of greatest commercial importance in Adams County—York Imperial and Stayman Winesap—are very susceptible to frog-eye.

6. Experiments were conducted for two years to find the exact time frog-eye infection takes place in order that spraying for its control could be worked out effectively. Meteorological records show that frog-eye infection is correlated usually with periods of rainfall when the temperature is sufficiently high for spore germination.

7. Some frog-eye infection takes place during the blooming period, but most of it occurs from the time the petals fall until two and one-half weeks later; in other words, when the leaves are in a growing condition.

8. The experiments for frog-eye control were conducted in three different orchards where a total of seventeen sprayed plots were utilized with an equal number of check plots. Five different fungicides were used, Bordeaux mixture, lime-sulphur, "Pyrox", "Sulfocide", and dust.

9. Bordeaux mixture, lime-sulphur, and "Pyrox", if applied at the proper times, are all effective for the control of frog-eye.

10. Bordeaux mixture gave slightly the best results with an average of 19.8 per cent infection for three sprayed plots; lime-sulphur an average of 21.5 per cent infection for nine plots, and "Pyrox" an average of 28.5 per cent infection for three plots. The seventeen check plots gave an average of 79.4 per cent frog-eye as compared with 23.3 per cent infection for all sprayed plots.

11. It is very evident that lime-sulphur, applied just before the blossoms opened, has decreased the per cent of infection on an average about 6.2 per cent. This decrease would hardly be sufficient to warrant the extra spray were it not for the fact that this early spray is by all means necessary for other troubles, such as scab.

12. Considerable foliage injury resulted from the use of copper sprays, Bordeaux mixture and "Pyrox". The injury was in the form of brown spots similar in appearance to young frog-eye spots. These spots did not seem to cause defoliation as did frog-eye. Lime-sulphur caused a slight amount of burning around the edges of the leaves.

13. "Sulfocide" was not sufficiently effective for use as a frog-eye spray. However, one trial does not offer proof conclusive enough to warrant discarding it for further trials.

14. The one trial with dust showed it to be ineffective. However, further trials are advisable.

15. The trees on the untreated plots were almost completely defoliated by September. The dusted trees on low ground were practically as severely affected as the check trees; whereas, the sprayed trees, with the exception of the sulfocide plot, held their foliage with very little dropping.

16. The size of the fruit was greatly affected. In the check plot and dusted Stayman Winesap block on low ground the fruit was very small and worthless except for cider. In the York Imperial dusted plot on higher ground, where defoliation was less severe, the fruit was better, though by no means standard; while the fruit in the lime-sulphur, Bordeaux and "Pyrox" plots was excellent except for sooty blotch, which was on all fruit.

The average size (greatest diameter) in inches of 1,000 miscellaneous apples from each Tyson plot of York Imperial receiving three applications in 1919 is as follows: "Sulfocide" 2.36; "Pyrox" 2.55; lime-sulphur 2.65; dusted York Imperial on high ground 2.28; dusted Stayman Winesap on low ground 2.13; check or unsprayed trees 2.06.

17. No russeting of the fruit was noticed in any of the plots.

18. For the control of frog-eye the following spray schedule is recommended:

1. Just before the blossom buds open.
2. When three-fourths of the petals have fallen.
3. Two weeks after No. 2.
4. About the middle of June.

The last spray is not necessary for practical control, but, if applied, should reduce frog-eye to a minimum. It is to be noted that these applications correspond closely to those recommended for the control of apple scab and codling moth.

In addition to spraying, the following suggestions are considered as being very important in controlling frog-eye:

1. Prune and burn all dead twigs, especially those killed by fire-blight.
2. Never allow brush to accumulate around the orchard.
3. Cultivate the orchard thoroughly, starting before blossoming time and continuing until mid-summer.

THE CONTROL OF FROG-EYE ON APPLE*

INTRODUCTORY

The purpose of this bulletin is to give the results of two years' work on the control of frog-eye, the common name for leaf-spot of apples. It is a very serious disease in parts of Adams County, Pennsylvania. Experiments for its control have been successfully conducted in other eastern states, but the writer is not aware of any systematic experiments carried on under Pennsylvania conditions. Consequently, considering the seriousness of the disease in parts of Pennsylvania, it was deemed advisable to work out the control of this fungus, and Adams County was selected as the locality best suited for conducting the experiment.

There are several orchards within a few miles of the State College Laboratory at Arendtsville, where the frog-eye is so serious every year that from 75 to 95 per cent of the leaves are infected, and by August three-fourths or more of the leaves have fallen. In these orchards the fruit is small and drops prematurely. The disease, by making repeated attacks year after year, has so weakened the trees that they have lost greatly in vigor and will eventually die if the disease continues unchecked.

A peculiar condition exists in that frog-eye is not spread broadcast over Adams County, but is more or less localized. It may be very severe in one grower's orchard and negligible in his neighbor's. In determining the reason for this peculiar condition several factors must be taken into consideration:

(a) Location of the orchard—whether on high or low ground or in close proximity to a body of water.

(b) Treatment the orchard has received and is receiving. Have the dead twigs and branches been pruned from the trees and burned? Has the orchard been kept in sod or has cultivation been practiced? What materials were used in making up the sprays and when were the applications made?

*Contribution from the Department of Botany of The Pennsylvania State College, No. 21.

Fig. 1. Frog-eye as it appears earlier in the season

Appearance of Frog-Eye

Frog-eye spots are first noticeable in abundance in Adams County about the third week in May, although scattering infections can be found a few days after the petals have fallen. The spots when first noticed are very small and purplish in color, but they rapidly enlarge and by the latter part of May become circular brown spots, from one-eighth to three-sixteenths of an inch in diameter. (Fig. 1). It is not until later in the season that the spots start to enlarge and form concentric circles with purplish, irregular, or lobed margins. The center, or the original spot, has by this time assumed a grayish color in contrast to the brown outer areas of secondary growth. It is not uncommon for the spots to have four or even more concentric rings by the lattter part of the summer. By this time the spots may attain a size of from one-fourth to one inch in diameter, the size depending upon the number of spots per leaf. (See Frontispiece).

Cause

Frog-eye is caused by a very low form of plant life—a fungus, and the particular one which produces it is quite different from the one which produces scab, rust and other fungous diseases of the apple. The fungus causing frog-eye is known as *Physalospora Cydoniae* Arnaud (*Sphaeropsis malorum*)[1] which is very common on dead apple twigs, and especially on twigs killed by fire-blight. This fungus is also the cause of black- rot which is sometimes destructive to fruit on the tree and in storage. This frog-eye fungus is capable of living on the growing leaves as well as on the dead portions of the tree, such as fruit, twigs, branches and fallen leaves. Here it forms small, black, pimple-like bodies in which countless numbers of spores are formed which are invisible to the naked eye. These, in turn, are capable of producing frog-eye spots. The spores ooze from the pimple-like bodies on the dead twigs and since they are so very small and light, are undoubtedly spread by the wind and other agencies, such as certain insects and the rain. The latter, by splashing and dripping, undoubtedly carries the spores from the sources of infection on the tree to the green leaves. When these spores come in contact with the leaves and the proper con-

1. Scott, W. M., and Rorer, J. B., Apple Leaf Spot caused by Sphaeropsis malorum. U. S. D. A., B. P. I. Bull. 121, 1908.

ditions of moisture and temperature are present, they germinate and develop germ tubes which penetrate the leaf surface. Here within the leaf tissues the fungus grows and eventually produces the circular spots which we call frog-eye.

This fungus which causes frog-eye has two stages commonly known as the imperfect and perfect. It is the common belief that the perfect stage is not instrumental in causing frog-eye and the

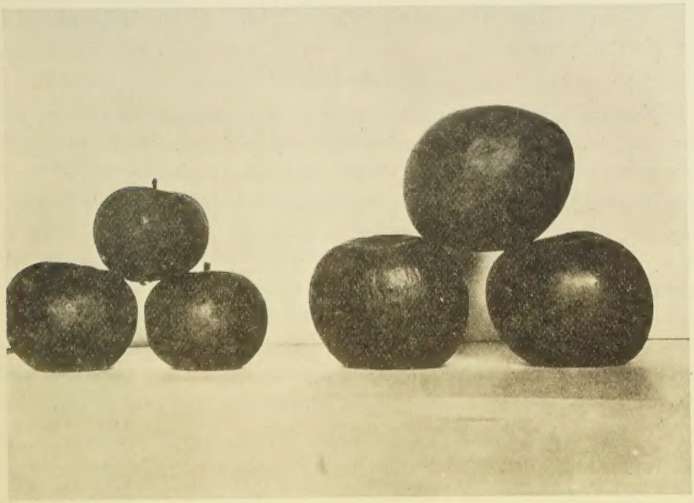


Fig. 2. Average size of sprayed and unsprayed York Imperial apples. Tyson Brothers orchard 1919. Photographed at apple harvest time

experiments of the writer support this general belief. Hesler[2] states that "The role of the ascosporic stage in hibernation is not certain", and goes on to say that "It would seem, therefore, that the ascospores from this source (apple) are of relatively little importance in initiating infections". The perfect stage is prevalent in Adams County.

Effect

Frog-eye causes serious damage by reducing the size of the fruit and results in lowering the vitality of the trees. This is ex-

2. Hesler, L. R., Black Rot, Leaf Spot, and Canker of Pomaceous Fruits. Cornell Univ. Agri. Exp. Sta. Bull. 379, 1916.

plained by the fact that the entire tree obtains its chief food for growth from the leaves. The leaves are the factories producing the food upon which the tree lives. When anything interferes with the foliage and reduces the leaf surface, no matter whether it is frog-eye, other fungous diseases, insect pests, or frost, the working capacity of these factories is greatly reduced and, in cases of severe attack, completely destroyed. With the food supply cut off, the tree naturally suffers from lack of nourishment, the size of the fruit is reduced (See Figure 2) and the next year's fruit buds either fail to form or are greatly weakened.

Infection

Extensive bagging experiments were conducted in 1918 to find the exact time when frog-eye infection takes place, and were partially repeated for the critical period of infection during 1919.

The bagging experiments consisted in tying paper bags securely over a large number of twigs before the buds burst and therefore before any leaf infection could take place. As soon as the leaves opened a number of the bags were removed for three days and then replaced. This process was repeated with successive twigs throughout the season so that by taking final data on all bagged twigs it was possible to determine the days when infection took place. A succession of such days constitutes a period of infection.

Figure No. 3 (1918 graph) shows the time and amount of frog-eye infection in 1918 from the time the blossom buds showed pink until the latter part of the summer. Table No. 1 shows that the growing season was divided for convenience into four periods: (1) Blooming period; (2) two and one-half weeks following the fall of the petals; (3) the month of June; (4) June 28 to August 19. The results show that 20.5 per cent of all the infection occurred during the blooming period; 61.6 per cent from the time the petals fell until two and one-half weeks later; 17.5 per cent from May 31 to June 27, and only .35 per cent from June 28 to August 19. In other words, the great bulk of infection occurred when the leaves were tender and succulent and infection practically ceased when the terminal buds formed.

Meteorological records kept during the time this experiment was conducted (See Table No. 1) show that during the spring months infection was greatest when the average daily rainfall was

heaviest. The summer months showed a greater average daily rainfall but at this time frog eye infection had practically ceased, due to the fact that the great majority of the leaves were no longer susceptible.

From the time the blossoms opened, the maximum temperatures on days when rainfall occurred were always sufficiently high for the germination of the spores. Only three rainy days occurred, and these during the blooming period, when the minimum temperature was so low that it might possibly interfere with germination.

The infection upon the leaves in 1919 occurred at approximately the same time as during the previous year. In 1918, 61.6 per cent of all the infection occurred from the time the petals fell until two and one-half weeks later. In 1919, the greater amount of infection took place within two and one half weeks after the petals fell, as shown by the graph in Figure No. 3. The curve also corresponds with the one for 1918, in that it shows but very little infection after the terminal buds formed.

A very important phase of this work is the relation which temperature and rainfall have to frog-eye infection. Table No. 2 shows this relation for the period from May 9 to May 26, 1919, during which time, as stated above, a very great amount of infection occurred. The table gives the maximum, minimum and mean temperatures for each day and for the entire period; and also, what is very important, the maximum, minimum and mean temperatures for the duration of each rainfall. It is interesting to note that the graph in Figure No. 4 for 1919 seems to rise and fall according to the precipitation. During the rainy periods indicated in Table No. 2 the mean minimum temperature was 50.9*; the mean maximum temperature, 59.7; and the mean for all the periods during which rainfall occurred, 54.92. For the entire period (May 9 to May 26, incl.) the mean maximum temperature was 66.66; the mean minimum temperature, 46.83; and the mean temperature for the period, 56.9. The highest temperature reached during any period of rain fall was 68.5.

Since sufficient moisture is one of the requirements of spores for germination, orchards situated in damp locations are more liable to attack from frog-eye as well as from other fungous diseases, providing the source of infection of these diseases is present. A favor-

*All temperatures are in degrees Fahrenheit.

able temperature is also absolutely essential. Consequently, throughout the entire spring of the year from blossoming time on, while the leaves are tender and succulent, conditions are usually very favorable for the development of the fungus which produces frog-eye and we find that the great bulk of infection takes place during this period. Hence, the sprays must be so applied as to give complete protection to the foliage throughout the month of May and possibly part of June.

Attention is called to the fact that the recommendations in this bulletin for the control of frog-eye are based upon the results of these experiments regarding time of infection.

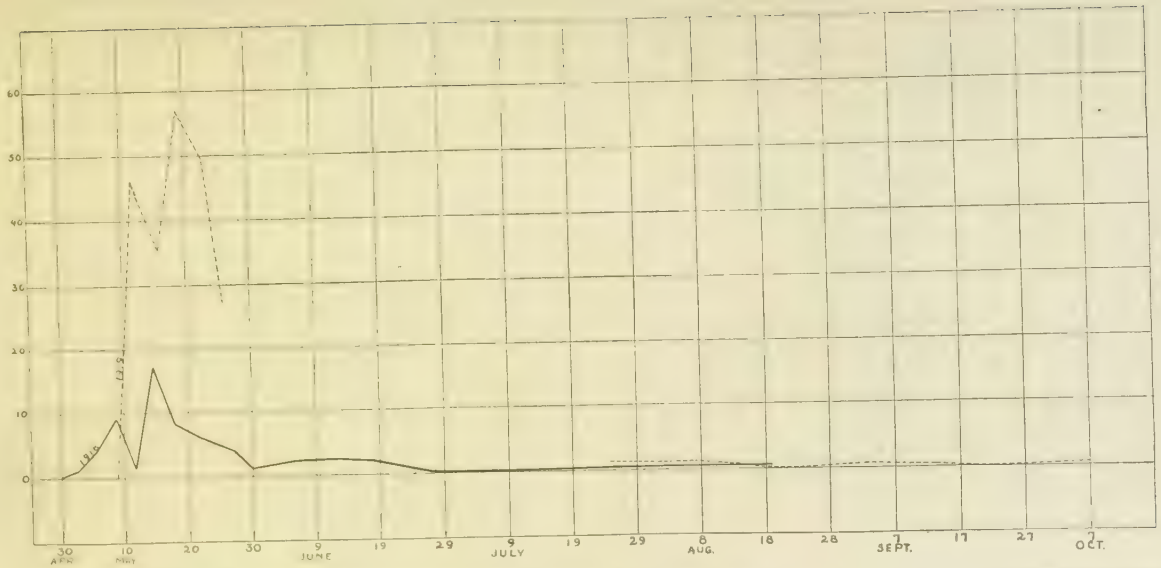
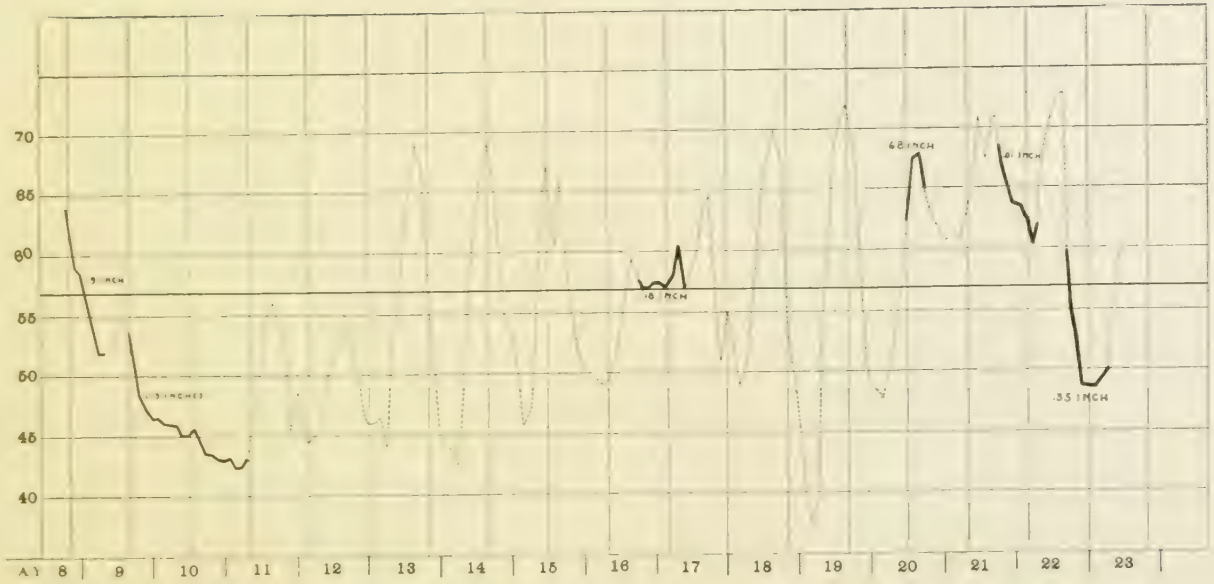


Fig. 3. Graphs showing the time and amount of frog-eye for 1918 and 1919. 1918—April 30-May 9 blooming period. 1919—Experiment was not started until May 9, the end of the blooming period.



FAHRENHEIT TEMPERATURE

Fig. 4. Graph showing the temperature and rainfall during a period of heavy frog-eye infection in May, 1919. The heavy lines indicate periods of rainfall. The heavy horizontal line indicates the mean temperature for the entire period.

Table 1. Frog-eye Infection by Periods in Relation to Rainfall and Temperature. 1918

Infection Periods	Total rainfall per period	Av. rainfall per day	Mean temperature per period		Percent infection
			Max.	Min.	
April 30-May 12 incl. (Blooming Period)	.71	.054	78.3	50.6	20.5
May 13-May 30 incl.	1.93	.101	82.3	58.6	61.6
May 31-June 27 incl.	1.73	.062	81.9	56.8	17.5
June 28-Aug. 19 incl.	8.92	.168	86.8	61.7	.35

Table 2. Temperature and Rainfall During a Period of Heavy Frog-eye Infection, May 9 to May 26, Inclusive. 1919.

Dates	Temperature			Rainfall		Temperature* During rainfall		
	Mean temp. (24 hrs.)	Max	Min	Amt.	Duration	Mean temp.	Max.	Min.
May 9	51.66	58	46	.90	**D. N.	57.38	64	52
End of Blooming Period				.26	4 P. M.-7 P. M.	50.75	53	49
May 10	44.75	46	43	.83	D. N. 7 P. M.	45.83	49	44
May 11	48.25	56	42	.10	D. N.	43.16	44	42
May 12	48.75	56	44					
May 13	55.00	69	43					
May 14	56.00	69	42					
May 15	56.08	68	46					
May 16	54.16	60	49					
May 17	58.41	65	51	.18	D. N. 10:30 A. M.	57.71	61	56
May 18	57.25	70	43					
May 19	56.16	72	36					
May 20	58.50	68	45	.68	12 Noon-6 P. M.	65.14	68	62
May 21	65.66	72	61					
May 22	62.08	73	47	.01	D. N.	64.45	68	61
				.25	5 P. M. 6:30 P. M.	56.66	60	55
May 23	55.50	66	45	.10	D. N.	48.58	55	44
May 24	59.50	75	44	.03		59.50	75	44
May 25	71.00	76	66					
May 26	65.50	81	50					

Mean Temperature for the period May 9 to May 26 ..... 56.90
Mean Maximum Temperature for the period May 9 to May 26 ..... 66.66
Mean Minimum Temperature for the period May 9 to May 26 ..... 46.83
Mean Temperature during periods of rain 54.92
Mean Maximum Temperature during periods of rain ..... [illegible]
Mean Minimum Temperature during periods of rain ..... [illegible]

*When rainfall occurred at night the temperature records were taken from the thermograph charts starting from 7 o'clock the preceding evening. This was done because the exact time the rainfall occurred at night was not known. When the rainfall started and terminated during the night the records were taken from 7 P. M. to 7 A. M.

**D. N. During Night.

Varieties Affected

In Adams County, practically all varieties grown are subject to frog-eye to a greater or less extent, but some varieties appear to be

more susceptible than others. The writer has seen York Imperial, Stayman Winesap and Ben Davis practically defoliated by frog-eye alone, but Yellow Transparent, Wealthy, Smokehouse, Williams Early Red and others in different locations, while also heavily infected, had less defoliation. There seems, however, to be but little difference in the resistance of varieties of apple to frog eye as compared with such diseases as cedar rust and blotch.

Experiments Conducted in 1918

So serious was the frog-eye situation in parts of the county that when the State College Laboratory was established at Arendtsville there was no doubt as to which fruit disease most needed the pathologist's attention. Frog-eye was by far the most serious. Consequently, numerous experiments were planned for work on this disease, but the two which received the most attention were "Control of frog-eye", and "Time when infection takes place".

Three bearing York Imperial orchards were selected where the disease had been so severe in past years that by August defoliation resulted. The owners of these orchards, Sheely Brothers, Tyson Brothers and J. L. Butt, have cooperated fully throughout the experiments. Two of these orchards were laid off into plots, each plot to receive different treatment. In the third orchard, Tyson Brothers, at Flora Dale, the control experiment was conducted on a very small scale, only one tree being used, one side of which was sprayed and one side unsprayed.

Conditions Existing in Sprayed Orchards

All three of the above named orchards afford ideal conditions for the development of frog-eye because portions of them are low and wet in the spring of the year with streams of water near-by. It is in these low areas that the frog-eye is always most severe. Two of these orchards have adjacent woodlots through which the streams of water flow. The close proximity of the streams and woodlots, combined with the low elevation of these parts of the orchards, would naturally afford excellent conditions for fungous development and would tend to keep that part of the orchards adjacent to the woodlots from drying off as early in the morning or after rains as they otherwise would. Figures 8, 11, and 18 show the location of the plots in the three orchards in relation to the streams and woodlots.

Treatment of Plots in 1918

The treatment which the various plots received in the three different orchards is recorded in the following table:

Table 3. Treatment of Plots in 1918

	Plot No.	Materials used: Fungicide	Materials used: Insecticide	Dates of sprays*	No. of sprays	Strength of sprays	Notes
Sheely Orchard	1	Lime sulphur	Arsenate of lead	Apr. 27, May 11, May 25	3	1-28½	Used home-made lime sulphur, Sp. Gr. 1.275. Powdered arsenate of lead used, 2 lbs. to 50 gallons except on May 25th in plots 1 and 3 when 1¼ lbs were used. Bordeaux mixture, 4 lbs. blue stone, 5 lbs. lump lime to 50 gallons water.
	2	Check. Untreated	Check. Untreated				
	3	Bordeaux Mixture	Arsenate of lead	Apr. 27, May 11, May 25	3	4-5-50	
	4	Lime sulphur	Arsenate of lead	May 11, May 25	2	1-28½	
	5	Check. Untreated	Check Untreated				
Butt Orchard	1	Lime sulphur	Arsenate of lead (May 2 & 10)	May 2, May 10, May 24	3	1-24	Used home-made lime sulphur, Sp. Gr. 1.240. Used powdered arsenate of lead, 2 lbs. to 50 gallons of spray except in Plots 3 double the amount of paste was used. Bordeaux mixture, 4 lbs. blue stone, 5 lbs lump lime to 50 gallons water. Used hydrated lime on May 24-25 adding an extra pound for every 50 gallons of spray.
	2	Check Untreated	Check Untreated				
	3	Lime sulphur	Arsenate of lead (May 10 11)	May 10-11, May 24	2	1-24	
	4	Check. Untreated	Check Untreated				
	5	Pyrox		May 10-11, May 24	2	8 lbs.-50 gals.	
	6	Check. Untreated	Check. Untreated				
	7	Bordeaux Mixture		May 11, May 24-25	2	4-5-50	
	8	Check. Untreated	Check. Untreated				
Tyson Orchard	1	Lime sulphur	Black Leaf 40	Apr. 30, May 27	2	1-30 (Apr. 30 1-27 (May 27	Used commercial lime sulphur. Black Leaf 40, one teaspoonful to one gallon of spray. Plots consisted of one tree only, one-half sprayed and one-half unsprayed. Used knapsack sprayer.
	2	Check. Untreated	Check. Untreated				

*April 27 and 30, May 2—Dates when the blossom buds were ready to open in the three orchards.
May 10 and 11—Three-fourths of the petals had fallen.

Method Used in Making Infection Counts

The method used in making the infection counts in order to obtain the per cent of infection and the number of spots, etc., was entirely impartial. One thousand leaves were secured from each plot and taken to the laboratory for examination. The 1,000 leaves were selected in the following manner: the person collecting the leaves went from tree to tree in each plot and cut off a small twig from a branch which was in each case toward the same point of the compass, regardless of the amount of infection it contained. The same method was used in check and sprayed plots alike, except where the check plots were limited in size, as was the case in the Butt orchard, in which case the leaves were collected at many points around the outside of the tree. By using this method, many more leaves were secured from each plot than were needed to make 1,000. The twigs from each plot were then mixed and as accurate counts as possible obtained.

The per cent of infection was based not on the number of spots but on the number of infected leaves. If there were 200 infected leaves among the 1,000 examined the per cent of infection would be 20. The number of spots recorded per 1,000 leaves was not estimated, but was the result of actual count.

Results in Sheely Orchard
1918

A glance at Table No. 4 will show that very good results were obtained in the Sheely orchard, and Figure 6 will give an idea of the amount of defoliation in one of the check plots on September 2 as compared with the adjacent sprayed plot. (Figure 5). On this date the trees of the check plots had dropped seven eighths of their leaves, while the sprayed trees had practically no defoliation. The only leaves which were not spotted with frog eye in the check plots were those which were forced out after the rest had fallen.

In Plot No. 4 where Bordeaux mixture was used there was a large amount of burning in the form of small circular spots which could easily be mistaken for frog eye. This type of injury has been noted by other workers, notably Crabill[3], Brooks and De Merritt[4], Stewart and Eustace[5], and Hedrick[6]. The spot is well represented by the accompanying illustration. (Figure 7). The actual damage done by the burning was not great, there being very little more defoliation in the Bordeaux mixture plot than in the lime-sulphur plots, where practically no burning occurred. However, the 34 per cent infection recorded for the Bordeaux mixture plot may be slightly high because of the difficulty in distinguishing the burned spots from the frog-eye.

Three sprays of lime-sulphur in Plot No. 1 reduced the amount of frog eye to 4.5 per cent less than Plot No. 5 receiving two sprays.

Table 4. Frog-eye Control for 1918*, Sheely Brothers Orchard, Cashtown, Pa.

Plot No.	Treatment	Applications		Percent Infection	Av. No. spots per infected leaf	No. spots per 1000 miscellaneous leaves
		No.	Time			
1	Lime sulphur	3	Apr. 27 May 11 May 25	26.1	2.89	756
2	Checks					
3	(No treatment)			72.9	10.59	7723
4	Bordeaux Mixture	3	Apr. 27 May 11 May 25	34.0	6.69	2276
5	Lime sulphur	2	May 11 May 25	30.6	2.67	820
6	Check (No treatment)			95.0	15.50	14730

*Infection was counted from September 23 to October 3.

3. Crabill, C. Harvey. The Frog-Eye Leaf Spot of Apples. Va. Agr. Exp. Sta. Bull. 209, 1915.

4. Brooks, Charles, and De Merritt, Margaret, Apple Leaf Spot. Phytopathology 2: 181-190, 1912.

5. Stewart, F. C., and Eustace, H. J., Two Unusual Troubles of Apple Foliage. N. Y. (Geneva) Agr. Exp. Sta. Bull. 220, 1902.

6. Hedrick, U. P., Cause and Control of Bordeaux Injury. N. Y. (Geneva) Agr. Exp. Sta. Bull. 287, 1907.

Fig. 5. Typical York Imperial tree sprayed with lime-sulphur. Sheely orchard. Photographed September 2, 1918

Fig. 6. Typical unsprayed tree in Sheely orchard. Photographed September 2, 1918

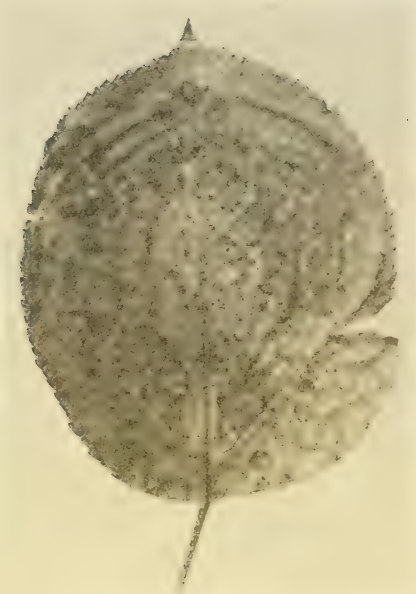


Fig. 7. Typical spray injury caused by copper sprays

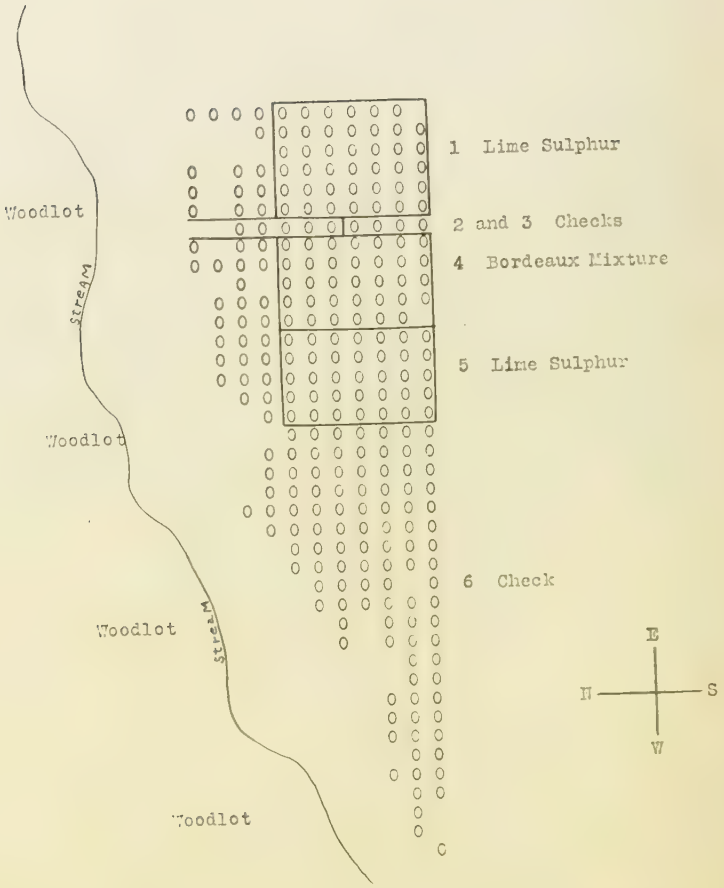


Fig. 8. Map of Sheely orchard showing the treated and check plots in relation to the woodlot and stream

Results in Butt Orchard

1918

Table 5 shows that excellent control was obtained in this orchard, the disease being reduced from as high as 83.2 per cent infection in one check plot to 11.7 per cent infection in a sprayed plot.

Here, as in the Sheely orchard, three applications of lime-sulphur give slightly better results than two.

It is interesting to note that the check for the pyrox plot has only 54.6 per cent frog-eye as compared to about 82 per cent in the other check plots. This is explained by the fact that the pyrox check plot received one spray by mistake on May 10 just before a very heavy rain storm.

The copper sprays, "Pyrox" and Bordeaux mixture, produced burning in this orchard in the form of small brown spots similar to those in the Bordeaux mixture plot in the Sheely orchard.

Table 5. Frog-eye Control for 1918*, J. L. Butt Orchard, McKnightstown, Pa.

Plot No.	Treatment	Applications		Percent infection	Av. No. spots per infected leaf	No. spots per 1000 miscellaneous leaves
		No.	Time			
1	Lime sulphur	3	May 2 May 10 May 24	11.7	1.73	203
2	No treatment			82.8	4.67	3873
3	Lime sulphur	2	May 10-11 May 24	13.0	1.53	199
4	No treatment			79.7	3.82	3048
5	Pyrox	2	May 10-11 May 25	26.4	1.85	489
6	No treatment except May 10		May 10 By mistake	54.6	2.73	1493
7	Bordeaux mixture	2	May 11 May 24-25	15.3	1.48	227
8	No treatment			83.2	3.60	2997

*Infection counts were made October 3rd to 13th.

Results in Tyson Orchard

1918

Table No. 6 shows that in spite of the fact that the work was done on only one tree, frog eye was reduced from 59.1 per cent infection on the check or unsprayed side of the tree to 30.3 per cent on the sprayed side.

At the time the second spray was applied, May 27, small frog-eye spots could be seen on both the sprayed and unsprayed sides of the tree, showing that the interval of one month's time between the two applications was too long. Had a spray been applied between these two, the amount of frog eye would in all probability have been negligible. As it was, the sprayed side of the tree stayed green long after the unsprayed side and the surrounding trees had dropped their foliage. The remainder of the orchard was dusted and apparently the dust had but very little effect in controlling the frog-eye.

Table 6. Frog-eye Control for 1918*, Tyson Brothers Orchard, Flora Dale, Pa.

Plot No.	Treatment	Applications		Percent infection	Av. No. spots per per infected leaf	Spots per 1000 miscellaneous leaves
		No.	Time			
1	Lime sulphur	2	Apr. 30 May 27	30.3	1.69	512
2	No treatment			59.1	7.62	4502

*One tree only was used, one side sprayed and one side unsprayed. Infection counts were made on September 19.

Combined Results for 1918

Table No. 7 shows the combined results obtained in 1918 in the three orchards. It will be seen that all three sprays, lime-sulphur, Bordeaux mixture and "Pyrox" were very effective in controlling frog-eye. The average infection for all sprayed plots is 24.4 per cent, while the average for the 8 check plots is 75 per cent including the one check plot sprayed by mistake. When the amount of frog eye infection can be reduced to 24 or even 30 per cent there is not enough frog eye present to be a serious factor and very little defoliation will result.

Table 7. Frog-eye Control for 1918. Combined Average Results. Three Different Orchards

Plot No.	Treatment	Applications		Av. per-cent in-fection	Av. No. spots per infected leaf	Av. No. spots per 1000 miscel-laneous leaves
		No.	Time			
1—Sheely 1—Butt	Lime sulphur	3	April 27, May 2, 10, 11, 24, 25	18.9	2.31	479
5—Sheely 3—Butt 1—Tyson	Lime sulphur	2	April 30, May 10, 11,24,25,27	24.6	1.96	510
1,5—Sheely 1,3—Butt 1—Tyson	Lime sulphur Av. of all 5 Plots	2.4	April 27, 30 May 2, 10, 11,24,25,27	22.3	2.10	498
4—Sheely 7—Butt	Bordeaux Mixture	2.5	April 27 May 11, 24, 25	24.6	4.08	1251
5—Butt	Pyrox	2.0	May 10, 11, 25	26.4	1.85	489
2, 3, 6—Sheely 2, 4, 6, 8—Butt 2—Tyson	Check. Not sprayed			75.0	7.36	5761

EXPERIMENTS CONDUCTED IN 1919

Although the results obtained in 1918 were very satisfactory, it was felt that in order to prove conclusively that frog-eye can be controlled, the work should be conducted one or possibly two more years. Consequently, experiments were planned, and the Tyson and Butt orchards used in 1918 were utilized again in 1919. The Butt orchard is now called the Riddlemoser orchard.

In the Riddlemoser (Butt) orchard four sprayed plots were laid off practically the same in all respects as in 1918 and the same sprays applied. The only change was a slight difference in the check plots. In the Tyson orchard four sprayed plots and one dusted plot were used in addition to the check plots.

Table 8. Treatment of Plots in 1919

	Plot No.	Materials Used		Dates of sprays*	No. of sprays	Strength of sprays	Notes
		Fungicide	Insecticide				
Riddlemoser (Butt Orchard	1	Lime sulphur	Arsenate of Lead June 2	May 2, May 13, June 2	3	1-30	Used home-made lime sulphur testing 33° Baume. Powdered arsenate of lead used at the rate of 3 to 4½ lbs. to 150 gallons of spray. The Bordeaux mixture was tested with yellow Prussiate of Potash. The Bordeaux was made from stock solutions. Black Leaf 40 was used at the rate of 1½ to 2 pints to 150 gallons. Used power sprayer and spray gun Pressure maintained at 150 to 175 pounds. For each sprayed plot there was a check plot of four trees except where an occasional tree was missing.
	2	Check. No treatment	Check. No treatment				
	3	Lime sulphur	Arsenate of lead	May 12, June 2	2	1-30	
	4	Check. No treatment	Check. No treatment				
	5	Pyrox	Arsenate of lead, May 2, 12, June 2, Black Leaf 40, May 12	May 2, 12, May 31-June 2	3	8 lbs. to 50 gals	
	6	Check. No treatment	Check No treatment				
	7	Bordeaux mixture	Arsenate of lead, Black Leaf 40	May 2, May 12	2	4-4-50	
	8	Check. No treatment	Check. No treatment				

TABLE 8—(Continued)

Tyson Orchard	1	Sulfocide	Calcium Arsenate	Apr. 30, May 13, May 26	3	1-200	Black Leaf 40—1½ pints to 200 gallons. Arsenate of lead powdered 4 lbs. to 200 gallons. Calcium arsenate 3 lbs. to 200 gallons. Used Hayes power sprayer on plot 1 with spray gun and maintained a pressure of 200 lbs. On plots 2, 3, and 4 used a compressed air outfit and a rod instead of a gun. Pressure maintained with this outfit was 80 lbs. All trees were sprayed from two sides, two leads being used, operated from the tower and ground. 36 trees in all were left as checks (plots 6-10) and received no treatment whatever.
	2	Pyrox	Black Leaf 40	Apr. 30, May 13, May 26	3	8 lbs. to 50 gals	
	3	Lime sulphur	Arsenate of lead, Black Leaf 40, Apr. 30	Apr. 30, May 13, May 26	3	1-33¼	
	4	Lime sulphur	Arsenate of lead, Black Leaf 40, May 13	May 13, May 26	2	1-33¼	
	5	Dust	15% Arsenic	Apr. 30 May 13 May 26	3	85% sulphur 15% Arsenic	
	6-10 incl.	Checks No treatment	Checks No treatment				

*April 30 and May 2 are the dates when the blossom buds were ready to open in the two orchards.
May 12 and 13 are the dates when three-fourths of the petals had fallen.

Results in Riddlemoser Orchard

1919

Table No. 9 shows that excellent results were again obtained in this orchard, the disease being reduced from as high as 66.2 per cent infection in the check plots to 10.7 per cent infection in the sprayed.

The lime-sulphur plot receiving three applications had 6 per cent less frog-eye than the one receiving two applications. This held true also last year, although the difference was not so pronounced. The "Pyrox" did not show up as well as the lime-sulphur and Bordeaux, although the 33.6 per cent infection was not sufficient to cause much defoliation. It should be noted that the Bordeaux plot No. 7, which received only two sprays, and one of these just before the blossoms opened, had only 10.3 per cent infection, whereas the lime sulphur plot No. 3 receiving two sprays, both after the petals fell, had 16.7 per cent infection. This was undoubtedly due to early infection during the blooming period.

A very peculiar thing happened in this orchard in that the frog-eye, which in 1918 was very severe, was not a serious factor in 1919, even on the unsprayed trees. It is true that it was present in sufficient quantity to give 66.2 per cent infection on unsprayed trees but this figure is hardly indicative of the amount present, because the highest average number of spots per infected leaf on the check trees was only 2.49. Even in the check plots there was not sufficient frog-eye to cause serious damage. The writer can offer only two possible reasons:

(1) A large brush pile of apple branches which had been left at the edge of the orchard for the past year or two was burned in the winter of 1918-19. This may have eliminated a source of infection.

(2) This orchard, which had been in sod for some time past, was thoroughly cultivated several times in 1919, beginning early in the spring. Possibly the fallen leaves are more of a source of infection than they are commonly supposed to be.

It is hardly likely that meteorological conditions could have been instrumental in lessening the amount of infection in this orchard because frog-eye was very severe in neighboring orchards. The

question arises whether cultivation and fertilization can stimulate growth and thereby make the trees more resistant. It has been observed that certain trees with unusually dense foliage and with leaves of abnormal size, obtained presumably by heavy applications of nitrogenous fertilizer, were severely attacked with frog-eye. The writer has also taken many records which show that small stunted leaves are never as severely infected as larger ones.

Even though the frog eye was not serious in this orchard there was enough to show that the disease could be controlled. A glance in the last column of Table No. 9 will show the relative amount of frog eye per 1,000 miscellaneous leaves in the various plots. Taking the bordeaux plot as an example, the amount of frog-eye was practically ten times as great in the check plot as in the sprayed. Figure 9 shows a typical York Imperial tree sprayed with Bordeaux mixture and Figure 10, a typical check, or unsprayed tree, in this orchard. The striking difference in the amount of foliage can readily be seen.

Table 9. Frog-eye Control for 1919, Riddlemoser (Butt) Orchard, McKnightstown, Pa.

Plot No.	Treatment	Applications		Percent infection	Av. No. spots per infected leaf	No. spots per 1000 miscellaneous leaves
		No.	Time			
1	Lime sulphur	3	May 2 May 13 June 2	10.7	1.55	166
2	No treatment			62.1	1.84	1145
3	Lime sulphur	2	May 12 June 2	16.7	1.43	239
4	No treatment			60.6	1.74	1056
5	Pyrox	3	May 2 May 12 May 31- June 2	33.6	2.27	763
6	No treatment			66.2	2.49	1651
7	Bordeaux Mixture	2	May 2 May 12	10.3	1.41	146
8	No treatment			66.1	2.19	1450

Fig. 9. Typical York Imperial tree sprayed with Bordeaux mixture. Riddlemoser (Butt) orchard. Photographed October 7, 1919

Fig. 10. Typical unsprayed check tree in the Bordeaux plot. Riddlemoser orchard. Photographed October 7, 1919

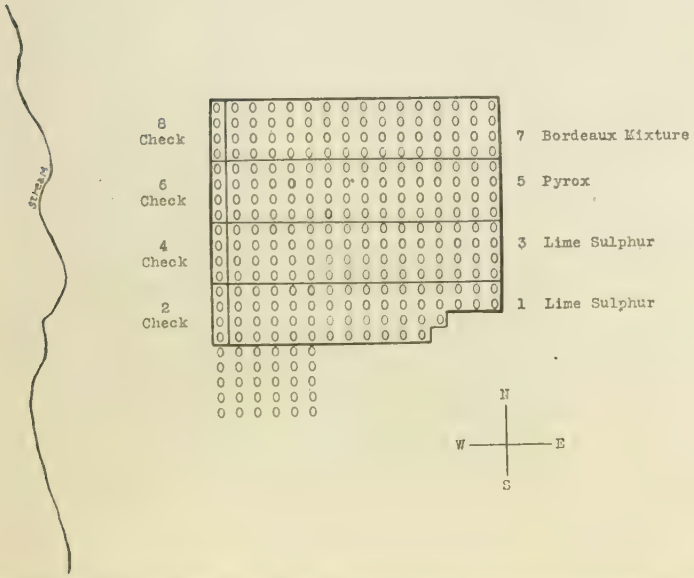


Fig. 11. Map of Riddlemoser (Butt) York Imperial orchard showing the treated and check plots and the stream nearby

Results Obtained in Tyson Brothers' Orchard

1919

An examination of Table No. 10 will show that for the fifth time in the two years the work has been under way, the results obtained for frog-eye control are very good. It is again evident that the spray applied just before the blossoms open (pink spray) reduces the amount of frog-eye. This time there is practically 7 per cent less infection in the lime-sulphur plot receiving three sprays than in the one receiving two.

The "Sulfocide" was not very effective for frog-eye although it did reduce the amount of infection from 98.9 per cent to 65.5 per cent.

The dust used was not sufficiently effective, there being 80.4 per cent frog eye in the plot (Figures 12 and 14). The portion of the dusted plot where the counts were made is the highest part of the orchard, where the frog-eye is never quite as severe as it is in

the lower parts. In a block of Stayman Winesap trees (Figure 13) which was dusted three times and which is on low ground, the disease was practically as severe as in the York Imperial plot receiving no treatment.

These plots attracted much attention because of the marked difference in the amount of foliage on the various plots. The check plot (Figures 16 and 17) and the block of dusted Stayman trees had lost practically all of their leaves by the latter part of the summer, while the dusted York Imperial trees on high ground and the sulfocide plot had lost fully 75 per cent. The sulfocide plot was not defoliated quite as severely as the dusted plot. The lime-sulphur and pyrox plots (Figures 14 and 15) were practicaly in full leaf by September 1, with only a slight amount of defoliation.

The last column of Table 10 shows the great difference in the amount of frog-eye in the various plots. These figures are accurate counts, and not approximated.

Table 10. Frog-eye Control for 1919, Tyson Brothers Orchard, Flora Dale, Pa.

Plot No.	Treatment	Applications		Percent infection	Av. No spots per infected leaf	No. spots per 1000 miscellaneous leaves	Av. size 1000 miscellaneous apples in inches (greatest diameter)
		No.	Time				
1	Sulfocide	3	Apr. 30 May 13 May 26	65 5	6.26	4100	2.36
2	Pyrox	3	Apr. 30 May 13 May 26	25.5	2.00	512	2.55
3	Lime sulphur	3	Apr. 30 May 13 May 26	23.5	3.21	755	2 65
4	Lime sulphur	2	May 13 May 26	30.6	3.35	1025	2.71
5	Dust* (High ground)	3	Apr. 30 May 13 May 26	80.4	11.66	9380	2.28
	Dust** (Low ground)	3	Apr. 30 May 13 May 26	96.0			2.13
6-10 incl.	Checks. No treatment			98.9	20.68	20454	2 06

*York Imperial on highest ground in orchard.

**Stayman Winesap on ground as low as where the check and sprayed plots are located. There was no check of this variety and therefore these trees have not been given a plot number.

Fig. 12. Typical dusted York Imperial trees on low ground. Tyson orchard. Photographed October 13, 1919

Fig. 13. Typical dusted Stayman Winesap trees on low ground. Tyson orchard. Photographed October 13, 1919

Fig. 14. Left—dusted. Right—sprayed with "Pyrox". Tyson orchard, variety York Imperial. Photographed October 12, 1919

Fig. 15. York Imperial tree sprayed three times with lime-sulphur. Tyson orchard. Photographed September 20, 1919

Fig. 16. Untreated York Imperial tree. Tyson orchard. Photographed September 20, 1919

Fig. 17. Left—unsprayed. Right—sprayed, foreground with "Sulfocide", background with "Pyrox" and lime-sulphur. Variety York Imperial

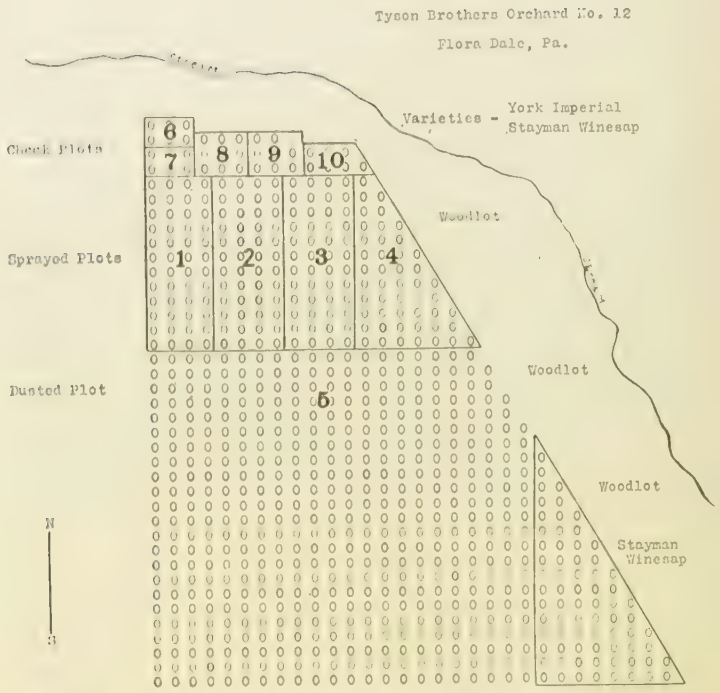


Fig. 18. Map of Tyson Brothers orchard No. 12 showing the treated and check plots in relation to the woodlots and stream. The plots received the following treatment: 1. "Sulfocide"; 2. "Pyrox"; 3. Lime-sulphur (3 applications); 4. Lime-sulphur (2 applications); 5. Dust; 6-10 incl. checks—untreated. The Stayman Winesap block was dusted.

Combined Results for 1919

Examination of Table No. 11 will show that excellent results were again obtained in 1919 with lime-sulphur, Bordeaux mixture and "Pyrox". Two materials, "Sulfocide" and dust, were also used in 1919, but were not found to be at all satisfactory for frog eye applications. Burning from the use of copper sprays, Bordeaux mixture and "Pyrox", occurred again. Although the number of burned spots was very great the damage was scarcely if at all noticeable in the color of the foliage even a short distance away from the trees.

Table 11. Frog-eye Control for 1919, Combined Average Results, Tyson and Riddlemoser (Butt) Orchards

Plot No.	Treatment	Applications		Percent infection	Av. No. spots per infected leaf	Av. No. spots per 1000 miscellaneous leaves
		No.	Time			
1 Butt 3 Tyson	Lime sulphur	3	Apr. 30 May 2, 13, 26 June 2	17.1	2.38	460
3 Butt 4 Tyson	Lime sulphur	2	May 12, 13, 26 Apr. 30	23.6	2.39	632
5 Butt 2 Tyson	Pyrox	3	May 2, 12, 13, 25, 31, June 2	29.5	2.13	637
7 Butt	Bordeaux mixture	2	May 2, 12	10.3	1.41	146
1 Tyson	Sulfocide	3	Apr. 30 May 13, 26	65.5	6.26	4100
5 Tyson	Dust* York Imperial	3	Apr. 30 May 13, 26	80.4	11.66	9380
2, 4, 6, 8 (Butt) 6-10 incl. (Tyson)	Checks No treatment			83.3	12.41	11952

*The dusted Stayman Winesap block is not included in these records because there was no check of this variety.

Combined Results for 1918 and 1919

The results of the two years' work prove conclusively that frog-eye can readily be kept under practical control. Of the five materials tried—lime-sulphur, Bordeaux mixture, "Pyrox", "Sulfocide" and dust—the first three were found to be very effective, while "Sulfocide" and dust cannot be recommended. Of the three which were effective, Bordeaux mixture gave slightly the best results with lime-sulphur a close second. Table No. 12 shows the complete results of the two years' work.

Table 12. Frog-eye Control for 1918-1919, Combined Average Results of Two Years' Work—Tyson, Sheely and Riddlemoser (Butt) Orchards

Plot No. 1918	Plot No. 1919	Treatment	Time and number of applications: No.	Time and number of applications: 1918	Time and number of applications: 1919	Av. percent infection*	Av. No. spots per infected leaf†	Av. No. spots per 1000 miscellaneous leaves‡
1 Sheely 1 Butt	1 Butt 3 Tyson	Lime sulphur	3	Apr. 27, May 2, 10, 11, 24, 25	Apr. 30 May 2, 13, 26, June 2	18.0	2.35	470
5 Sheely 3 Butt 1 Tyson	3 Butt 4 Tyson	Lime sulphur	2	Apr. 30, May 10, 11, 24, 25, 27	May 12, 13, 26 June 2	24.2	2.13	559
1, 5 Sheely 1, 3 Butt 1 Tyson	1, 3 Butt 3, 4 Tyson	All 9 Lime sulphur Plots	2.4	Apr. 27, 30, May 2, 10, 11, 24, 25, 27	Apr. 30 May 2, 12, 13, 26 June 2	21.5	2.23	519
4 Sheely 7 Butt	7 Butt	Bordeaux mixture	2.3	Apr. 27, May 11, 24, 25	May 2, 12	19.8	3.19	883
5 Butt	5 Butt 2 Tyson	Pyrox	2.5	May 10, 11, 25	Apr. 30 May 2, 12, 13, 26, 31 June 2	28.5	2.04	588
	1 Tyson	Sulfocide			Apr. 30, May 13, 26	65.5	6.26	4100
	5 Tyson	Dust			Apr. 30, May 13, 26	80.4	11.66	9380
2, 3, 6 Sheely 2, 4, 6, 8 Butt 2 Tyson	2, 4, 6, 8 Butt 6, 7, 8, 9 10, Tyson	Checks. No treatment				79.4	10.04	8451

*The highest percent of frog-eye in any one check plot was 99 and in any one sprayed plot 34.
†The highest average number of spots per leaf was 20.
‡The highest number of spots per 1,000 leaves was 20,454.

General Remarks

Experiments for the control of frog-eye have been conducted by other workers, notably Scott[7], Brooks and De Meritt[4], and Crabill[3], in other states, but heretofore no work has been conducted in Pennsylvania. These experiments have shown that this disease is relatively easy to keep in check, providing the proper applications are made at the proper times. Timeliness and thoroughness are of the utmost importance in spraying for the control of frog-eye, as they are for the control of most diseases. While frog-eye is usually, if not always, more severe on the outside branches, yet, in cases of severe attack, there is always sufficient infection on the foliage of the inside branches to cause defoliation. Therefore, it is important that the trees be thoroughly covered with spray at all points.

The results of the two years' work warrant the statement that frog-eye can readily be controlled by three or even two applications of either Bordeaux mixture, lime-sulphur, or "Pyrox" provided they are given at the right times.

The cost of the various materials used in the experiments, based on the current market prices, is as follows:

100 gals.	Bordeaux Mixture (8-10-100)	$ .77
100 gals.	"Pyrox" @ $ .20 (16-100)	3.20
100 gals.	Lime-Sulphur (1-33⅓)	.66
100 gals.	"Sulfocide" (1-200)	.60
100 gals.	Lead Arsenate (3 lbs. powdered)	.96
100 gals.	"Black Leaf 40" (¾-pint)	1.00
100 lbs.	Dust (85 lbs. sulphur, 15 lbs. lead arsenate)	10.50

Acknowledgements

The writer is indebted to the owners of the orchards in which these experiments were conducted for their generous cooperation; also to Mr. S. W. Frost, Field Entomologist at the Arendtsville Laboratory, for taking data during his illness in the spring of 1919. To these men and to the members of the Botany Department at The Pennsylvania State College the writer gratefully acknowledges his indebtedness.

3. Ibid.
4. Ibid.
7. Scott, W. M., Bur. Plant Ind. Bull. 93. 27, 1906.